How to design living hinges for 3D Printing

Written by Ben Redwood

This article discusses design rules and the best materials to use when producing 3D printed hinges.

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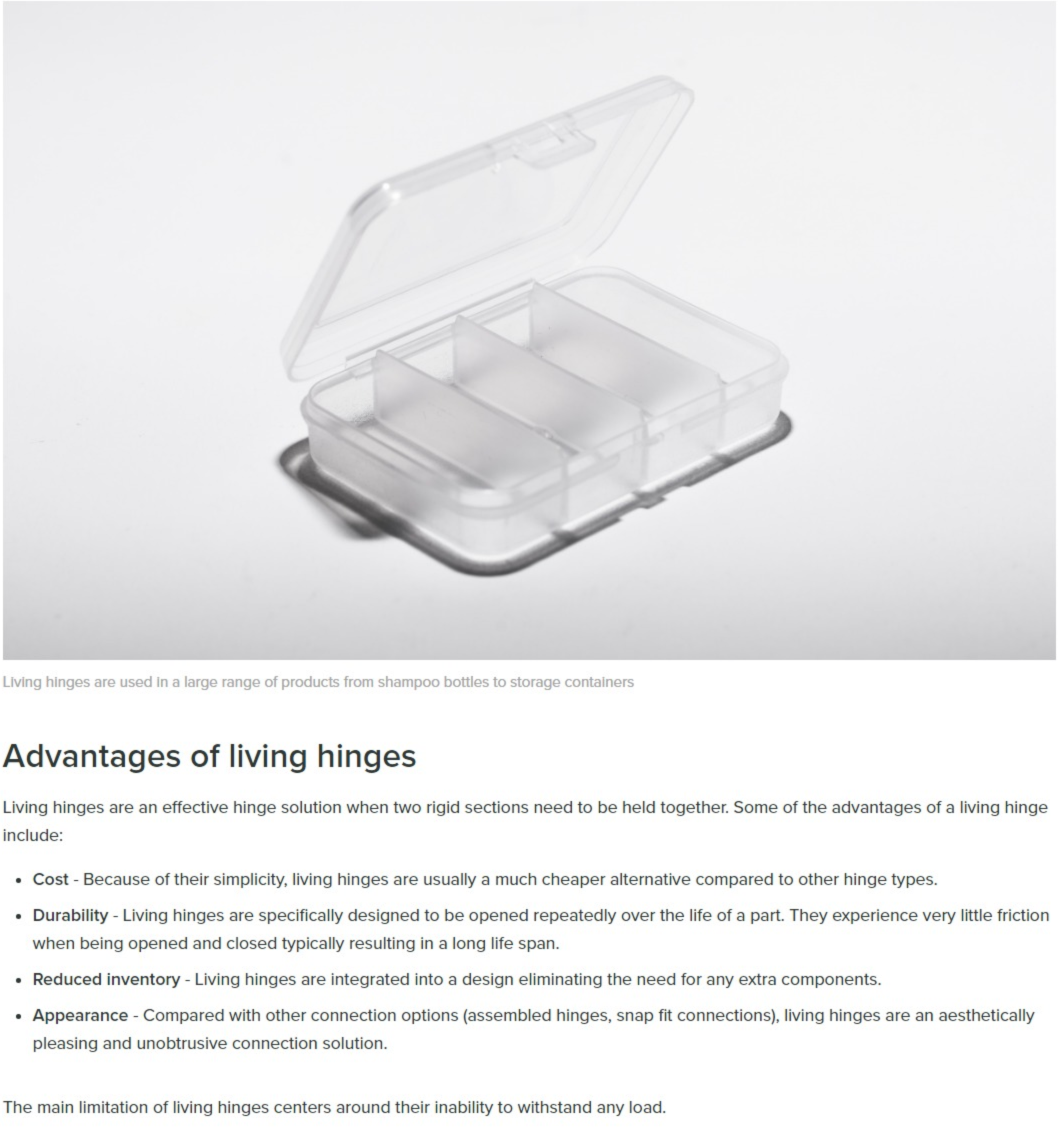
Introduction

Living hinges are a low cost, simple method of connecting 2 rigid pieces of plastic. This article will present the advantages of using living hinges and discuss design rules and material recommendations when using 3D printing to produce living hinges.

What are living hinges?

A living hinge is a thin flexible web of plastic that connects two or more rigid sections. Typically the larger rigid sections and the living hinge will be made of one continuous piece of plastic. The low cost and simplicity of living hinges make them a popular option for many applications. They can be found on everything from drink and shampoo bottles to workshop storage containers and food packaging. Living hinges and the associated rigid sections are manufactured almost exclusively via injection molding.



Living hinges are used in a large range of products from shampoo bottles to storage containers

Advantages of living hinges

Living hinges are an effective hinge solution when two rigid sections need to be held together. Some of the advantages of a living hinge include:

- **Cost** - Because of their simplicity, living hinges are usually a much cheaper alternative compared to other hinge types.
- **Durability** - Living hinges are specifically designed to be opened repeatedly over the life of a part. They experience very little friction when being opened and closed typically resulting in a long life span.
- **Reduced inventory** - Living hinges are integrated into a design eliminating the need for any extra components.
- **Appearance** - Compared with other connection options (assembled hinges, snap fit connections), living hinges are an aesthetically pleasing and unobtrusive connection solution.

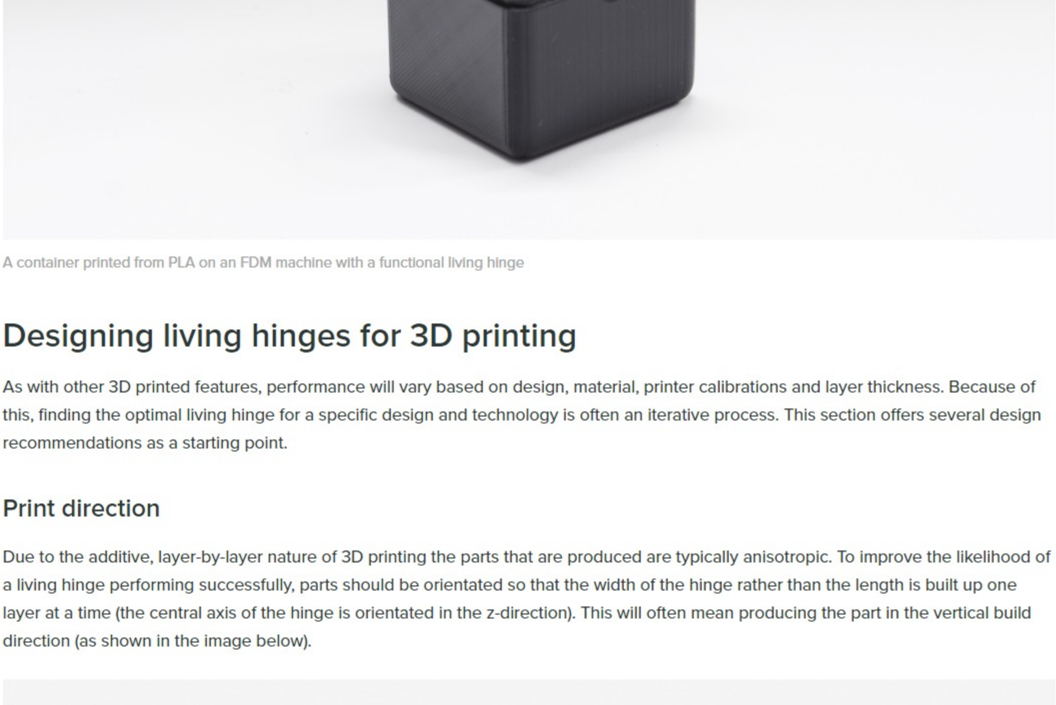
The main limitation of living hinges centers around their inability to withstand any load.

3D printed living hinges

While injection molded living hinges are designed to withstand thousands of cycles without breaking, the nature of 3D printing (anisotropic, brittle, layer-by-layer construction) means that 3D printed living hinges are typically used for prototyping or proof-of-concept models where a small number of cycles are needed. This makes 3D printed living hinges best suited for the verification of a design before needing to invest in expensive injection molding tooling.

The main benefits of 3D printing a living hinge are:

- No need for expensive tooling.
- The design does not need to incorporate features essential to injection molded parts such as gates, runners or sprues.
- Designs can easily be altered and iterated to achieve the optimal design.
- 3D printing is able to produce parts quickly further accelerating the design process.



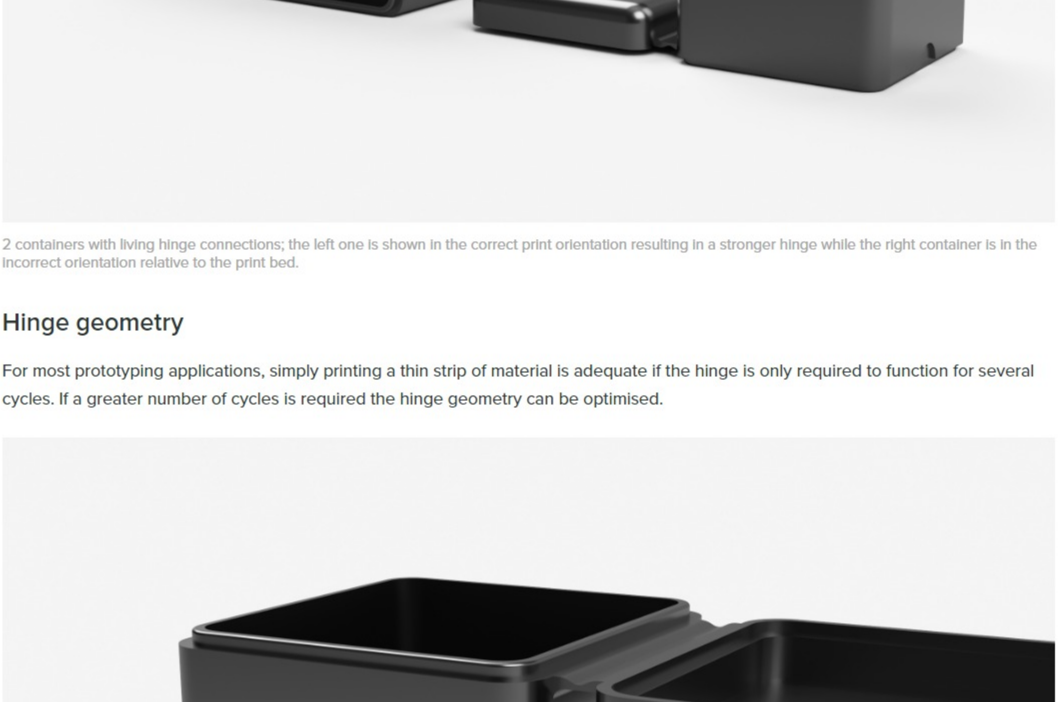
A container printed from PLA on an FDM machine with a functional living hinge

Designing living hinges for 3D printing

As with other 3D printed features, performance will vary based on design, material, printer calibrations and layer thickness. Because of this, finding the optimal living hinge for a specific design and technology is often an iterative process. This section offers several design recommendations as a starting point.

Print direction

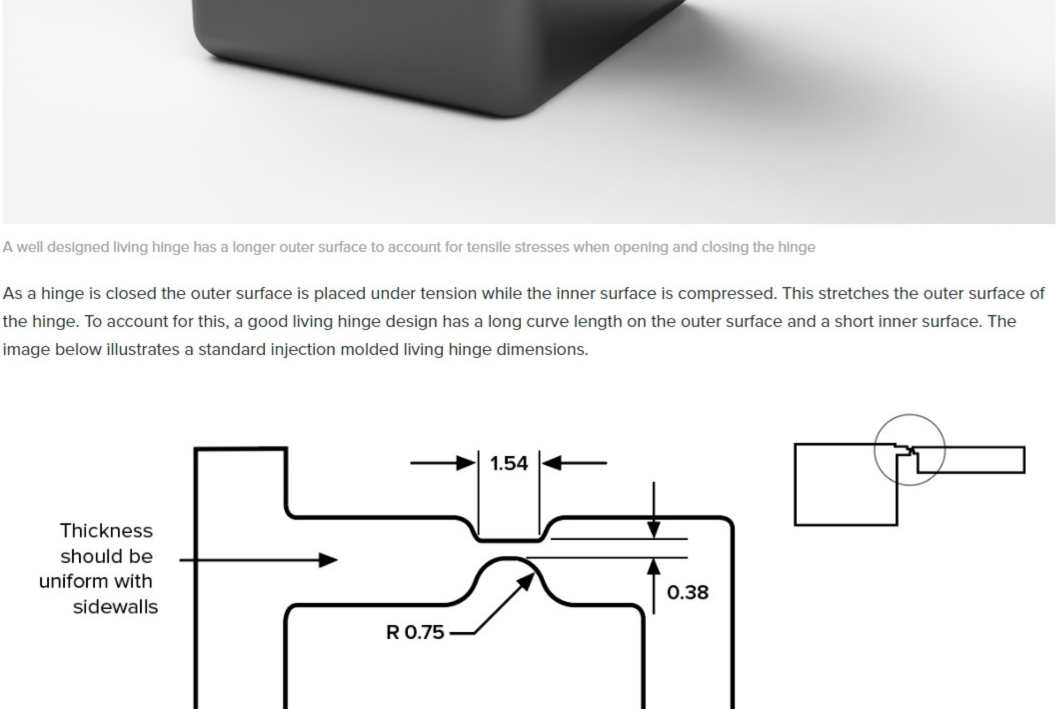
Due to the additive, layer-by-layer nature of 3D printing the parts that are produced are typically anisotropic. To improve the likelihood of a living hinge performing successfully, parts should be orientated so that the width of the hinge rather than the length is built up one layer at a time (the central axis of the hinge is orientated in the z-direction). This will often mean producing the part in the vertical build direction (as shown in the image below).



2 containers with living hinge connections; the left one is shown in the correct print orientation resulting in a stronger hinge while the right container is in the incorrect orientation relative to the print bed.

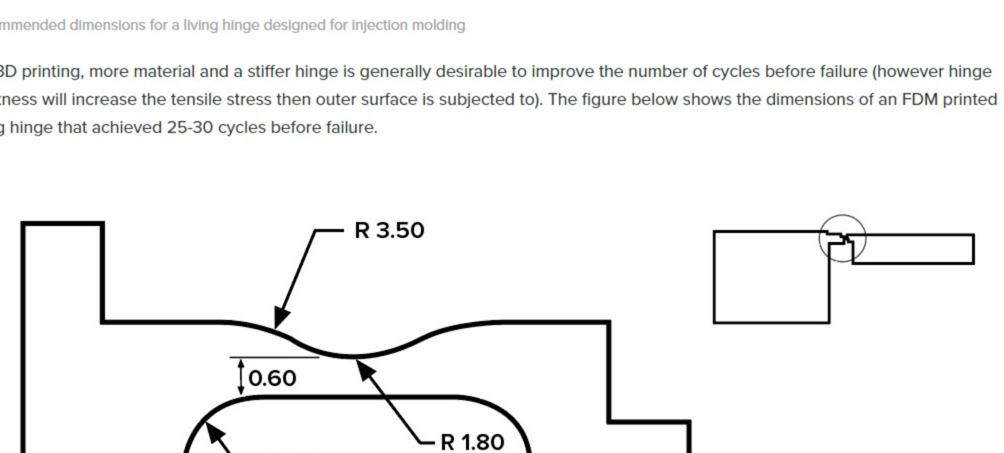
Hinge geometry

For most prototyping applications, simply printing a thin strip of material is adequate if the hinge is only required to function for several cycles. If a greater number of cycles is required the hinge geometry can be optimised.



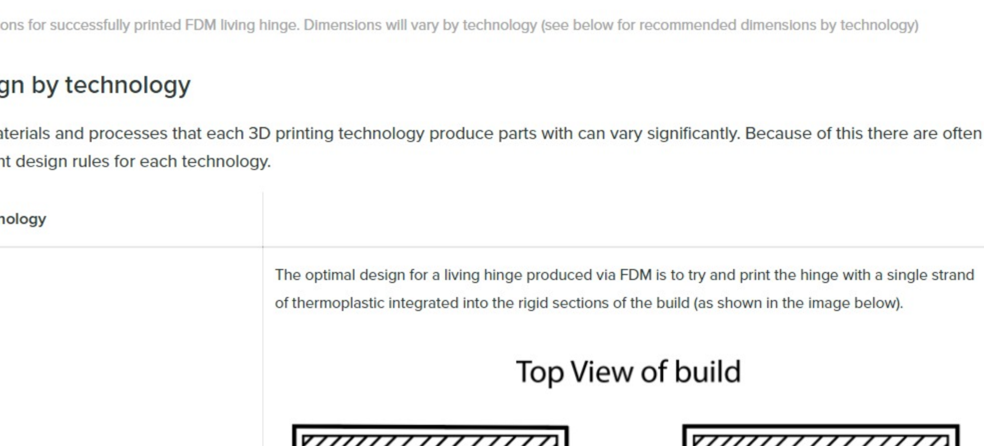
A well designed living hinge has a longer outer surface to account for tensile stresses when opening and closing the hinge

As a hinge is closed the outer surface is placed under tension while the inner surface is compressed. This stretches the outer surface of the hinge. To account for this, a good living hinge design has a long curve length on the outer surface and a short inner surface. The image below illustrates a standard injection molded living hinge dimensions.



Recommended dimensions for a living hinge designed for injection molding

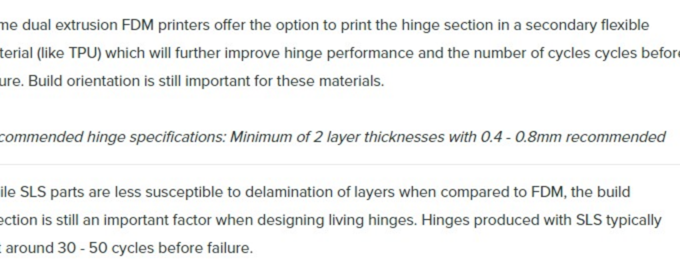
For 3D printing, more material and a stiffer hinge is generally desirable to improve the number of cycles before failure (however hinge thickness will increase the tensile stress then outer surface is subjected to). The figure below shows the dimensions of an FDM printed living hinge that achieved 25-30 cycles before failure.



Dimensions for successfully printed FDM living hinge. Dimensions will vary by technology (see below for recommended dimensions by technology)

Design by technology

The materials and processes that each 3D printing technology produce parts with can vary significantly. Because of this there are often different design rules for each technology.

Technology	
FDM	The optimal design for a living hinge produced via FDM is to try and print the hinge with a single strand of thermoplastic integrated into the rigid sections of the build (as shown in the image below).  The living hinge should be printed in a single strand of thermoplastic to improve strength This will result in a vertical build direction meaning a large amount of support material will be required to successfully complete the print. This will add cost and time to the build. Some dual extrusion FDM printers offer the option to print the hinge section in a secondary flexible material (like TPU) which will further improve hinge performance and the number of cycles cycles before failure. Build orientation is still important for these materials. *Recommended hinge specifications: Minimum of 2 layer thicknesses with 0.4 - 0.8mm recommended*
SLS	While SLS parts are less susceptible to delamination of layers when compared to FDM, the build direction is still an important factor when designing living hinges. Hinges produced with SLS typically last around 30 - 50 cycles before failure. *Recommended hinge specifications: 0.3 - 0.8mm thick and a minimum of 5 mm in length.*
Material jetting	Parts produced via material jetting are typically more isotropic than both FDM and SLS. The parts are very smooth and are often aesthetically comparable to injection molded parts. The rigid photopolymers used for general material jetting printing are brittle and unsuitable for prototypes where more than 10 cycles are required. One of the major advantages of some material jetting printers is the ability to produce multi-material prints. By printing the hinge section in a flexible material (like TangoBlack) a living hinge design can be produced that will last a large number of cycles. *Recommended hinge specifications: 0.4 - 0.8mm thick.*

Post processing

Living hinges can be annealed after printing to increase the number of cycles before failure. This is can be achieved by heating up the hinge (gently running a flame over the hinge to heat it up to a soft, flexible state without melting it) and then working it back and forth for several cycles at the elevated temperature before leaving it in the closed position to cool. The effect of this procedure will depend heavily on the material used and the geometry of the hinge. For the FDM hinge example shown in the images above, this greatly increased the number of cycles the hinge could withstand before failure.

Recommended materials

Injection molded living hinges are made almost exclusively from polyethylene and polypropylene plastic. Both materials are flexible and soft with a relatively low melting point.

For 3D printing, materials that have a high elongation before break and good tear resistance are optimal. The recommended materials for each process described above are summarised in the table below.

Technology	Recommended material
FDM	Nylon 12
FDM (multi material)	*Rigid section:* Any rigid thermoplastic *Living hinge:* TPU, Semiflex, Ninjaflex
SLS	PA 12 or PA11
Material jetting	Simulated polypropylene
Material jetting (multi material)	*Rigid section:* Any rigid photopolymer *Living hinge:* TangoBlack, VisiJet elastomers

Rules of thumb

- Living hinges made via 3D printing are best suited for proof of concept designs before investment in expensive injection mold tooling.
- Living hinge geometry should have a long outer surface path and a short internal path.
- Dimensions and materials for the best suited 3D printing technologies for producing living hinges are summarised in the table below:

Technology	Dimensions	Material
FDM	0.4 - 0.6mm	Nylon 12
SLS	0.3 - 0.8mm thick and a minimum of 5 mm in length	PA 12 or PA11
Material jetting	0.4 - 0.8mm thick	Simulated polypropylene

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